

Applying Electroencephalography in Establishing Safety Criterion by Measuring Mental Fatigue in Industrial Workers: A Case Study

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ABSTRACT: This paper details the use of Electroencephalography, a methodology commonly applied for medical purposes such as in detection of mental disorders and in upcoming technological research areas like BCI (Brain Computer Interfaces), is now re-purposed to use in the Manufacturing sector to reduce the risk of error and anomalies. Manufacturing involves many tasks that require mental alertness of an operator who supervises a particular process, failure to do this, might leave unchecked errors in the finished product. Fatigue could lead to serious consequences to health of the worker and may also lead to on-job accidents. To minimize possibility of such instances, a study has been conducted to measure and find ways to tackle issues of mental fatigue. To quantify the study, we have taken the case study of Pharmaceutical Sector where this kind of study might have some impact. [3] The study reveals that workers doing tasks that require high alertness develop fatigue earlier than anticipated, and therefore need frequent rotation from such activities.

KEYWORDS: EEG, Manufacturing, Mental Fatigue, Inspection, Normalized Attention Levels

PRELUDE: Electroencephalography (EEG) is an electro- physiological monitoring method to record electrical activity of the brain. It is typically noninvasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used such as in electrocorticography. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp. Diagnostic applications generally focus either on event-related potentials or on the spectral content of EEG.

In this study, the major focus lies on applying the brainwave technology in an industrial setting without getting into very fundamentals of brainwave technology. In a nutshell, there are broadly five classes of brainwaves that is, α waves (7 - 13 Hz), β waves (13 - 40 Hz), γ waves (40 - 80 Hz), θ waves (4 - 7 Hz) and δ waves (0 - 4 Hz). Each wave corresponds to certain kinds of brain activities like alertness, cognitive tasks like problem solving, subconscious, REM sleep, non- REM sleep [7] etc. A commercial EEG sensor such as Neurotic Mind wave, which uses a proprietary algorithm based on relative powers of fore-mentioned waves gives an output of alertness of the subject on a normalized scale (1-100) is utilized for the study.

I. INTRODUCTION

Mental Alertness is imperative in several manufacturing processes where in, for instance, continuous inspection of goods moving on conveyor belts is required (or) parameters from a machine have to be continuously read/monitored and specific actions have to be performed based on it (or) workers might have to put together parts on an assembly line. In all such tasks, there is a need for high mental alertness and thus the probability of human induced errors increases [5]. These human induced errors are very difficult to track as they are very qualitative and skill based, many of which is outside the scope of automation. In addition, many of the manufacturing system, have a standard operating procedure(SOP) which contains a information about best manufacturing practices, how can one reduce operating anomalies and if encountered, details the process of redressal. In the study conducted, lack of mental alertness has been established as a dominant contributor in human induced errors. [4][6]

The recent use of brain waves and EEG technology in medicine has shown tremendous improvement in helping diagnosis of mental disorders. Building upon this fact, the study utilizes to use of normalized alertness data from the brainwave sensor which quantifies the state of human mind's mental alertness and consciousness can be used to establish the argument mentioned previously. Moreover, many studies have suggested that mental fatigue induces deterioration in cognitive abilities. Mental fatigue causes reactions become prolonged, more floatable, and more error tending. [1][2] Though there are several manufacturing areas which have numerous manufacturing pro-

cesses requiring various levels of mental alertness, the study only considers a particular case study of pharmaceutical sector only. Later, this model which is established on the sector can be extended and reworked on other sectors too.

II. SETTING UP THE EXPERIMENT

Having taken the particular case of the Pharmaceutical sector, the preliminary task was to identify production processes which are susceptible to fallacies due to lack of mental alertness, which have been detailed in the table below.

Processes of Pharmaceutical Manufacturing			
STAGE	ACTIVITY	EQUIPMENT	ALERTNESS LEVEL
Dispensing	Weighing & Dispensing	Booth, Balance	Moderate
Granulation	Granulate Powder	FBD, Blender Mill	Light
Compression	Granule Compression & Processing	Rotary Compression Machine	Moderate
Coating	Coat Tablets	Automatic Coating Machine	Light
Inspection	Inspect Tablets	Inspection Belt	Intense
Packing	Packing tablets into blisters in turn into boxes and shippers	Blister Packing Machine & Autocartentator	Moderate

FIG. 1.

From all these activities, the selection of activity requiring highest alertness level that is, tablet inspection has been taken into consideration for the study.

A. Process Parameters

- Work Type: Visual Inspection
- Equipment : Inspection Belt
- Area : Tablet Inspection
- Temperature : 298 K
- Humidity : NMT 55% RH
- Lighting : NLT 500 lx (On the Workbench), NLT 400 lx (In the Room)

B. Test Group

A random sample of 37 factory workers across 7 industrial plants¹ from Inspection area has been taken into consideration. The test group consisted of 24 males and 13 females.

All candidates have adequate inspection training as testified by the pharmaceutical company. In addition, all workers have been medically examined including eye examination, and have been found fit for the task. See

Test Group Demographics			
CRITERIA	MEAN	MIN	MAX
AGE	28.78	26	34
EXPERIENCE	1.78	1	4.5
<i>**All subjects are medically examined including vision</i>			
<i>**All subjects are given adequate training and are fit for the job as testified by respective industry plant</i>			

FIG. 2.

Equipment: For purposes of this study, to get optimum results, a commercial EEG sensor (Neuro Sky Mind wave) which has been pretested for accuracy has been selected. This sensor sends packets of alertness data sampled at 120 samples/hour via Bluetooth to an Arduino Bluetooth module which it then sends it to a laptop through Arduino micro-controller. This data is saved for processing in a .csv file.

Procedure: Every test subject first wears the brainwave head set; all wireless connections such as Bluetooth are thoroughly tested until proper signal strength occurs for a continuous interval of time. The subjects are then advised to continue normal execution of their respective tasks to get authentic results. Every subject is monitored for a continuous interval of four hours in sets of two i.e., before and after lunch-time. The actual readings are taken after first 10-15 minutes after the work commences, this is done so that brainwave attention data stabilizes hence minimizing fluctuation errors. The threshold of mental fatigue is assumed to be in this manner: "if the normalized attention data stays at a level of less than 50% of its initial value for a time interval of 10 minutes or more, then a state of mental fatigue is considered to have occurred."

Data Collection and Processing: After data is collected and cleaned, all the data points at each timestamp are averaged out to plot unified trends over all test subjects and variance is calculated. The data is then plotted as shown in Fig3.

Mental Fatigue Measure				
PARAMETER	MEAN	VARIANCE	MIN	MAX
Normalised Alertness Measure On Scale (0 to 100)				
Initial	74	27.8	59	87
After 4 hours (Lunch Break)	34	2.3	31	38
After 8 Hours (End of Shift)	31	13.6	26	43
Time Measured in Hours				
Time Until Fatigue (pre-break)	3.40	0.11	3.14	3.88
Time Until Fatigue (post-break)	3.28	0.16	2.99	3.71

FIG. 3.

III. OBSERVATION AND CONCLUSION

On observing the mean trends, it is found that a state of mental fatigue based on the definition stated previously, occurs at 3 hours 24 Min (3.40 Hours) in pre-break session and 3 hours 17min (3.28 Hours) in post-break session. Due to the drop-in alertness level we can conclude that these might lead to safety or quality issue. Working under low alertness level might lead to an accident affecting the worker or a human induced error which might affect the inspection process; unchecked errors might aggravate and slow down the manufacturing process. Therefore, for this particular case study i.e., the case of pharmaceutical industry, the shift changes or personnel Rotation should take place every 3 hours instead of two shifts of 4 hours, for personnel employed in areas that require a high level of mental alertness. Since different manufacturing processes have a variety of requirements, hence this kind of study needs to be performed for the particular manufacturing process and then studied over a considerable diverse group (both in number, gender and ethnicity), should be documented and subsequent results should be documented in the Standard Operating Procedure (SOP) in accordance with the results obtained.

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The selection of industrial plants is done based on convenience sampling in Ahmedabad, India and surrounding areas.